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Document de Travail
Working Paper

EA 4272

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2013/01

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Abstract

In this paper we examine the Environmental Kuznets Curve (EKC) hypothesis using the Ecological Footprint (EF), a more comprehensive indicator of environmental degradation, through a time-series analysis for 15 countries covering the 1961-2007 period. We first test the EKC hypothesis from traditional linear, quadratic and cubic functions, with standard and logarithmic specifications. The EKC hypothesis is only supported for Chile and Uruguay with the quadratic functional form. We also find that most of the countries exhibit a positive linear relationship between the EF and GDP. Finally, we study the long-term relationship between the EF and GDP. The results show evidence of long-term relationship between income and EF for some countries (Brazil, Chile, China, and Uruguay). More particularly, Spain displays a cubic relationship, in an N-shaped function form.

Keywords: Environmental Kuznets Curve; Ecological Footprint.

JEL Classification: Q0; Q01; C32.

1 Introduction

Environmental issues are becoming a priority, even in political and economical fields. Authorities have to control actions which have an impact on our ecosystems, notably due to the current threats regarding climate change or natural disasters. It is therefore not only a matter of our production and consumption sustainability but also and especially our survival. Achieving sustainable development is becoming a main objective for authorities. They need to know how to act, and more precisely if economic growth allows improvement to the environment or damages it. It is thus useful to analyze the Environmental Kuznets Curve (EKC) hypothesis.

An Environmental Kuznets Curve (EKC) is a hypothesized relationship between economic development and environmental quality. This curve indicates that economic development initially damages environmental quality, but with further development the relationship appears to reverse and environmental degradation starts to reduce. This relationship produces an inverted U-shaped curve, where environmental degradation first rises and then falls with increasing economic development.[1] The idea of EKC came the fore in 1991 with the Grossman and Krueger's study of the North American Free Trade Agreement (NAFTA) (Grossman and Krueger, 1991; Stern, 2004), though the idea of Kuznets curve (relationship of economic growth and income inequality) existed since 1955 (Kuznets, 1955). Panayotou (1993) first coined the term EKC (see also Selden and Song, 1994). However, the EKC hypothesis became very important after 1991 for its potential and promise of finding a final solution to environmental degradation. If this hypothesis is taken to be true, then the future environment may be assumed to be pollution-free whilst also possessing higher living standards.

In some cases, an N-shaped EKC has been found as well (e.g. Torras and Boyce, 1998). It occurs when environmental degradation shows a positive, negative and positive relationship, respectively, with economic development. It means environmental degradation first increases with economic development, and then decreases after a certain level, thus forming a peak. Along with further increase economic development, however, degradation tends to rise again, which

[1] The main explanation of this relationship would be the result of three different effects: scale effect, technological effect and composition effect (Grossman and Krueger,1991; Panayotou, 1997; De Bruyn et al., 1998; Begun and Eicher, 2007; Meunié and Pouyanne, 2007; *inter alia*). There is another main explanation corresponding to the demand for environmental quality (Barrett and Graddy, 2000).

creates a trough in the EKC.[2]

However, the results are mixed. Several factors may explain the different results: the countries considered for analysis (developed or developing), the historical period considered, the environmental indicator used, and the method employed to estimate the relationship, amongst others (e.g., Cavlovic et al., 2000; Harbaugh et al., 2002).

Most of studies of the EKC hypothesis use an environmental indicator specific pollution measurement, such as SO_x or NO_x, or a global pollution measurement, such as CO_2, as the environmental pressure indicator. See Lieb (2004), Stern (2004), Winslow (2005) and Miah et al. (2010), for a summary of the different studies of the EKC for various pollutants. These particular pollutants are only a small part of environmental concerns on a global level. Consequently, the analysis performed in this paper tests the validity of the EKC using a much more comprehensive measurement of environmental degradation, the Ecological Footprint (EF). The choice of the EF as an aggregate measurement of environmental quality can be explained by the fact that its limitations are well-known, it is a widely referenced measurement of sustainability (Nijkamp et al., 2004; Haberl et al., 2001), and has been adopted by a growing number of government authorities, agencies, and policy makers as a measurement of ecological performance (Wiedmann et al., 2006).

To the best of our knowledge, the existing literature on EKC hypothesis with the EF as environmental pressure indicator contains only a few empirical studies. Wackernagel et al. (1997), Boutaud, Brodhag and Gondran (2004), and Bagliani, Bravo and Dalmazzone (2008) perform a cross-section data – due to a lack of data – whereas Caviglia-Harris, Chambers and Kahn (2009) use panel data. However, when studies use panel data techniques, particular attention must be paid to heterogeneity (sometimes unobserved) between countries because different countries could exhibit different turning points (if present) of the relationship between environmental quality and income (List and Gallet, 1999). Thus, an approach with standard panel data techniques, which assumes that one form fits all EKCs, can lead to a biased interpretation of results. As Stern (1996) suggested, a valid approach to overcome the heterogeneity issue between countries is to study the EKC hypothesis of individual countries. This approach allows researchers to model

[2]The main reason is that after a period of modernization of production processes, efficiency opportunities disappear (De Bruyn et al., 1998; Dinda et al., 2000).

the relationship between a measurement of environmental degradation and income taking into account the specific historical experiences of each country. In literature, only a small number of studies have investigated individual countries. In this paper, we analyze the EKC hypothesis in a time-series dimension for 15 countries (developed and developing) covering the 1961-2007 period. Since there is no consensus on the functional forms of the EKC and the transformation of data, we examine the EKC hypothesis from linear, quadratic and cubic forms as well as with data in standard and logarithm forms.

Furthermore, previous studies using time series data lack a diagnostic analysis of the order of integration of the variable entering the long-term relationship as implied by the EKC, which could lead to spurious regression bias (Granger and Newbold, 1974). Empirical work on the EKC using time series should consider data properties, because appropriate methods of inference depend greatly on whether data is stationary or non-stationary. If there is no cointegration in a posited regression among non-stationary variables, interpreting the results in the classical way is invalid. Cointegration testing is a powerful test of misspecification (Perman and Stern, 2003). Specifically, studies in a time-series dimension have mainly estimated the EKC relationship using error-correction models (ECM), but only with CO_2 as a proxy of environmental degradation (e.g., Jalil and Mahmud, 2009; Iwata et al., 2010; Fodha and Zaghdoud, 2010). In this paper, we use the cointegration tests of Johansen (1988, 1991) to examine the possible long-term relationship between the EF and GDP.

This article is organized as follow: Section 2 describes the EKC model. Section 3 briefly presents the ecological footprint as environmental pressure indicator. Section 4 provides a survey of literature on the EKC using the EF. The empirical results are given in Section 5. Finally, Section 6 concludes.

2 EKC model

As we said above, the use of panel data is highly questioned in the field of EKC analysis. As a result, we have chosen to base our study on time series data. Moreover, this issue has to been studied over the long-term because the development of pollution is simultaneous with the economic development process which is not detectable in short-term. We are aware that we need a very large series to study this process, however such data is often unavailable.

The original EKC literature considers GDP or log GDP in quadratic form. We have chosen to perform both the functional forms due to the fact that there is no consensus about the question of logarithms. Moreover, more recent papers have added cubic functions of GDP (or log GDP) to test for a second potential turning point. Following such standard practice, the EKC equations can be specified in traditional linear, quadratic or cubic form.

The linear form is given by:

$$EF_t = b_0 + b_1\, GDP_t + \epsilon_t \tag{1}$$

where EF_t stands for the per capita ecological footprint (g ha) during period t and GDP_t for the per capita GDP per period. b_0 denotes a constant term and ϵ is the normally distributed error term. If $b_1 > 0$, the relationship between GDP and EF is linearly increasing. Any increase in income leads to a proportional increase in EF: the ecological footprint may worsen as per capita income increases. It reflects the scale effect that we discussed earlier. The relationship would be monotonically decreasing if $b_1 < 0$. In both cases, the link between environment and income only exists if b_1 is significant.

The quadratic form is the traditional one in EKC studies, defined as:

$$EF_t = b_0 + b_1\, GDP_t + b_2\, GDP_t^2 + \epsilon_t \tag{2}$$

The EKC hypothesis holds if $b_1 > 0$, $b_2 < 0$, and both are statistically significant. Therefore, a turning point and an inverse U-shaped relationship could exist. With these assumptions, there is a de-linking relationship between GDP and EF. The turning point is obtained by setting the first derivation (with respect to income) of our equation equal to zero and solved for income and is given by:

$$Y^* = \frac{-b_1}{2\, b_2}$$

In this case, environmental pressure increases at initial growth stages but at a decelerating rate, up to a threshold. However after this phase, growth allows improvements in the environmental state. Indeed, the two other effects are important enough to more than offset the scale effect.

If $b_1 < 0$ and $b_2 > 0$, a U-shaped pattern is obtained, which is particularly bad for sustainable development assumptions. We note that they may only be an inflexion point and no turning point, so that, the relationship could be increasing or decreasing at different rates.

Finally, the cubic form of the EKC is given by:

$$EF_t = b_0 + b_1\,GDP_t + b_2\,GDP_t^2 + b_3\,GDP_t^3 + \epsilon_t \tag{3}$$

This equation describes a relationship with two potential turning points. Indeed, if $b_1 > 0$, $b_2 < 0$ and $b_3 > 0$, we are facing an N-shaped function. After an initial EKC-like phase, environmental pressure begins to increase again thereafter. But only one inflection point could exist (an increasing or decreasing relationship). The inflection point is obtained in the same way: by setting the second derivation of our equation equal to zero and solved for income, and is given by:

$$Y^\circ = \frac{-b_2}{3\,b_3}$$

3 The Ecological Footprint as an environmental pressure indicator

The Ecological Footprint (EF) was introduced by Rees (1992) and further developed in Wackernagel and Rees (1996) to determine how the environmental damage associated to human consumption compares to the biosphere's regenerative capacity. The EF estimates the amount of natural capital (measured in a biologically productive surface area) needed to support the resource demand and waste absorption requirements of a population and is expressed in global hectares or hectares of globally standardized bioproductivity (Wackernagel et al., 2004a, 2004b). Specifically, the EF "measures the human demand on nature by assessing how much biologically productive land and sea area is necessary to maintain a given consumption pattern" (Wiedmann et al., 2006) or "measures the amount of biologically productive land and water area an individual, a city, a country, a region, or all of humanity uses to produce the resources it consumes and to absorb the carbon dioxide emissions it generates with today's technology and resource management practices" (Global Footprint Network, GFN).

In the basic calculation of the EF, consumption (categorized by food, services, transportation, consumer goods, and housing) is divided by the predetermined yield (biological productivity) by land type including cropland, pasture, forest, built-up land, fisheries, and energy land. The ability of these areas to supply ecological goods and services (i.e. the predetermined yield) depends on the biophysical characteristics of the land (such as soil type, slope, and climate) in addition to socio-economic choices (such as management decisions and technological inputs). This indicator had been created in terms of surface area, and thus is expressed as a single unit: global hectares (gha).[3]

However, the measurement is not all inclusive as it neglects atmospheric ozone levels, and does not account for pollutants that are difficult to convert to land or water ecosystem equivalents, such as methane and sulfur (Rees, 2000). The EF is an indicator centered only on the use of renewable resources. The assumptions that are made to convert this encompassing measurement into a single unit have lead to much of its criticism.

Despite these shortcomings, the EF represents a powerful indicator of the dynamics of renewable resource use, capturing a significant share of environmental pressure both on the input side and output side. This comprehensive view is particularly important in studying the EKC whose aim is describing a general relationship between economy and the environment (Bagliani et al., 2008). The EF is a widely referenced measurement of sustainability (Nijkamp et al., 2004; Haberl et al., 2001), and has been adopted by a growing number of government authorities, agencies, and policy makers as a measure of ecological performance (Wiedmann et al., 2006).

4 A brief survey on the EKC with the EF

The existing literature on EKC with the EF as environmental pressure indicator contains only a few empirical studies.

Wackernagel et al. (1997) study the EKC using 1993 EF data for 52 countries on four functional forms: linear, quadratic, log-linear, and log-quadratic. Their results show that the estimation of the quadratic EKC supports the EKC assumption, with a turning point corresponding to 21 587$.

[3] Since 2003, the EF calculations are made by the GFN, a non governmental organization created by Wackernagel and Burns. Data is available in the *Living Planet Reports*, published by the World Wildlife Fund (WWF). Note that the EF is a consumption-based indicator.

However, this level of income does not belong to the sample. Moreover, the log-quadratic function seems lead to a monotone linear increasing relationship. Bagliani, Bravo and Dalmazzone (2008) extend the work of Wackernagel et al. (1997) by analyzing the EKC from consumption-based measures, using 2001 EF data for 141 countries. They study several functional forms (linear, quadratic and cubic) of EKC, in standard and logarithmic specifications. They do not find evidence of EKC hypothesis assumptions. They also linearly introduce biocapacity to the regressions as a further independent variable and find that biocapacity is significant.

York, Rosa and Dietz (2004) analyze the cross-national variation in the EF, i.e. variations in eco-efficiency, using data for the 1999 EF for 139 countries in 1999. They find that eco-efficiency is generally higher (EF intensity is lowest) in developed countries, but this level of efficiency does not appear to be sufficient magnitude to compensate for their large productive capacities.

Boutaud, Gondran and Brodhag (2006) examine the EKC by using two alternative indicators in order to avoid several theoretical and empirical biases: the EF as environmental pressure indicator and the Human Development Index (HDI) as economic development indicator. Their cross-country study for 128 countries does not support the EKC hypothesis from these indicators, using 2000 EF and HDI data.

Caviglia-Harris, Chambers and Kahn (2009) investigate the EKC hypothesis using panel data of the EF for 146 countries covering the 1961–2000 period. They find no empirical evidence of an EKC relationship between the EF and economic development, and only limited support for such a relationship among the components of the EF.

5 Empirical Results

5.1 Data

For the purpose of our analysis, we consider annual time series data for per capita Ecological Footprint (EF) and per capita Gross Domestic Product (GDP) for 15 countries covering the period 1961-2007. Our analysis focuses on Argentina, Brazil, Canada, Chile, China, Colombia, France, India, Norway, Paraguay, Peru, Portugal, Spain, Sweden, and Uruguay. We study different kinds of countries in term of development phase, geographical location or production structure. The EF data (consumption side) comes from the Global Footprint Network (GFN).[4] Per capita GDP, expressed in constant US$ prices for the year 2000, has been obtained from the World Bank.

It is important to note that we worked on a large range of countries: On average, the per capita ecological footprint is between 0.899 (for India) and 6.500 (for Canada). Concurrently, per capita GDP belongs on average to the interval 307.546 (India) and 24143.7 (Norway). Descriptive Statistics are shown in Table 1.

5.2 Results

We first perform unit root tests to study the stationarity of the series. More precisely, we apply ADF (Dickey and Fuller, 1981) and ADF-GLS (Elliott et al., 1996), taking into account either a constant or a constant and a trend. The results show that for each country both time series (EF and GDP) are integrated of order one, I(1), i.e. are non-stationary.[5] To avoid spurious regressions one of the solutions is to make the series stationary by differencing. However, differencing of the series would prevent long-run analysis. In order to circumvent this problem, a number of techniques can be employed to test for the existence of the long-run equilibrium relationship (cointegration) among the time series variables. We thus perform Johansen tests (1988, 1991) to detect the number of long-run relationships.

We estimate two types of EKC models – linear, quadratic and cubic, in standard or logarithm form – from OLS: (1) baseline EKC models on series in first differences (i.e. a short-run relationship); and (2) EKC relationship using error-correction models (ECM) (i.e. short-run and long-run relationships), if a long-run relationship exists.

Tables 2 and 3 display the results of the EKC estimations for the data in level form. The EKC hypothesis is only supported for Chile and Uruguay with the quadratic functional form. For Chile, the coefficient of GDP is 18.0 ($\times$ 10^{-4}) and is statistically significant positive sign that implies 1% increase in income will lead to 18.0% ($\times$ 10^{-4}) increase in the EF. The statistically significant negative sign of GDP^2 confirms the delinking of EF and income at income high levels.

[4]Global Footprint Network, 2010. National Footprint Accounts, 2010 Edition. Available online at http://www.footprintnetwork.org.

[5]The results are available upon request.

The turning point of income turned out to be US$ 6199.30 compared to the highest value in our sample of US$ 6078.40. This result gives support to the EKC hypothesis that the level of EF initially increases with income, until it reaches its stabilization point, then it declines. Furthermore, we find that most of the countries exhibit a positive linear relationship between the EF and GDP, with the exceptions of Argentina, Norway, Sweden and Uruguay. For example, the GDP coefficient is 4.56 and statistically significant for Brazil that implies a 1% increase in income will lead to a 4.56% ($\times 10^{-4}$) increase in the EF.
Tables 4 and 5 give the results of EKC estimations for the data in logarithm form. We do not find an inverted U-shaped relationship, showing that the transformation of the data can bias the results. We find that the linear relationship is statistically significant and positive for all the countries, except for Argentina, Norway and Sweden. This result confirms the assumption of a monotone linear increasing relationship between GDP and the EF. Furthermore, Brazil and India respectively display a quadratic and cubic relationship but not with the expected signs. Note that for these two countries the $\overline{R}^2$ is higher than from the linear relationship.

Once a long-run relationship has been established from the Johansen's cointegration tests an error-correction model can be estimated for the EKC hypothesis from the following regression (with a linear, quadratic or cubic form):

$$EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + b_3 GDP_t^3 + b_4 EC_{t-1} + \epsilon_t \tag{4}$$

The results of the ECM then allow measuring the adjustment speed required to adjust to long-run values after a short-term shock from the error-correction (EC) coefficient. Tables 6 and 7 display the estimation results of the ECMs, when a cointegration relationship has been detected, for both series in level and logarithm forms. The results do not support the EKC hypothesis. However, we find long-run relationship between GDP and EF for India, Spain, Sweden from data in level form and for Brazil, Chile, China and Uruguay from data in both forms. All the error-correction coefficients (b_4) are correct in (negative) sign and significant. For example, this coefficient is -0.400 for Spain, implying, 40% of the disequilibria in EF of the previous year's shock adjust back to the long-run equilibrium in the current year. Note that this long-run relationship improves the $\overline{R}^2$ and thus the fit of the model, showing the importance of taking this type of relationship into account . For example, the $\overline{R}^2 = 0.27$ from the quadratic relationship for Brazil (in logarithm form) and we obtain $\overline{R}^2 = 0.45$ from the quadratic relationship by adding the error-correction coefficient.

More interestingly, the results show short- and long-run relationships for several countries. Spain displays a cubic relationship from data in level form, taking an N-shaped function form. The coefficient of GDP is 59.8 ($\times 10^{-4}$) and statistically significant positive sign that implies a 1% increase in income will lead to a nearly 60% ($\times 10^{-4}$) increase in the EF. The statistically significant negative sign of GDP^2 ($b_2 = -5.74(\times 10^{-7})$) confirms the delinking of EF and income at high levels of income, but the statistically significant positive sign of GDP^3 ($b_3 = 0.19(\times 10^{-10})$) shows that the relationship between income and EF increases again. It means environmental degradation first increases with economic development, and then decreases after a certain level, thus forming a peak. Along with further increases in economic development, however, degradation tends to rise again, which creates a trough in EKC. Furthermore, Uruguay exhibits a positive linear relationship from data in both forms. Brazil is well represented by a cubic relationship from data in level form, and by a quadratic relationship from data in logarithm form. Finally, China exhibits a quadratic relationship from data in logarithm form.

Environmental politics are very important whatever the level of economic development of the country considered. It is important to notice that, the ecological footprint, is mostly made up of carbon dioxide emissions and this result complies the literature. To conclude, when we taking into account the environment as a whole instead of a specific form of pollution, the relationship between growth and environment doesn't seem to be and EKC type and need authorities involvement, particularly in the environmental field.

6 Conclusion

In this paper we examined the Environmental Kuznets Curve (EKC) hypothesis using the Ecological Footprint (EF), a more comprehensive indicator of environmental degradation, in a time-series dimension for 15 countries covering the 1961-2007 period. We first tested the EKC hypothesis from traditional linear, quadratic and cubic functions, in standard and logarithmic specifications. The EKC hypothesis is only supported for Chile and Uruguay with the quadratic functional form. We also found that most of the countries exhibit a positive linear relationship between the EF and GDP. Finally, we studied the long-run relationship between the EF and

GDP. The results showed evidence of long-run relationship between income and EF for some countries exhibit (Brazil, Chile, China, and Uruguay). More particularly, Spain displayed a cubic relationship, taking a N-shaped function form.

To conclude, environmental policies are central: growth would appear to be not enough to improve environmental condition even when growth becomes cleaner. Indeed, we have chosen a consumption-based approach in order to capture the potential delocalization effects. Even if developed countries mainly produce services which are not as polluting as industrial goods, the consumption behavior of their inhabitants haven't changed. As a result, the level of demand of developed countries for polluting goods is still increasing. In these conditions, there is no hope of a turning point for the relationship between economic growth and the ecological footprint. On the other hand, we know that the EF suffers from several deficiencies in knowledge, so future research would be focussed on natural resource measurement and we would try to overpass the EKC concept that also suffers from several empirical biases.

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Table 1: Descriptive Statistics

Country	Variable	Mean	Min	Max	Std. Dev	Skewness	Excess Kurtosis
Argentina	EF	3.556	2.361	5.133	0.838	0.154	-1.442**
	GDP	6826.22	4956.22	9388.69	902.976	0.302	0.336
Brazil	EF	2.845	2.584	3.145	0.137	-0.252	-0.590
	GDP	3024.68	1548.13	4297.74	818.448	-0.761**	-0.763
Canada	EF	6.500	3.532	9.293	0.965	-0.365	1.579**
	GDP	17627.3	9479.82	26192.9	4630.51	0.108	-0.886
Chile	EF	2.381	1.573	3.325	0.459	0.276	-0.950
	GDP	3164.63	1867.61	6078.40	1315.18	0.830**	-0.814
China	EF	1.447	1.064	2.214	0.298	0.786**	-0.226
	GDP	465.568	72.3249	1864.11	461.951	1.384***	1.031
Colombia	EF	2.142	1.834	2.356	0.150	-0.612*	-0.624
	GDP	2050.80	1214.20	3083.13	515.685	-0.068	-1.066
France	EF	4.674	3.610	5.184	0.403	-0.866**	-0.231
	GDP	16198.0	7668.31	23584.6	4613.69	-0.215	-1.026
India	EF	0.899	0.814	1.080	0.062	1.077***	0.816
	GDP	307.546	147.477	687.591	133.821	1.115***	0.463
Norway	EF	5.419	3.101	15.065	1.956	3.013***	12.105***
	GDP	25143.7	11276.4	41900.8	9530.58	0.208	-1.205*
Paraguay	EF	3.838	2.956	4.672	0.346	-0.554	0.427
	GDP	1166.26	682.186	1488.95	291.558	-0.605*	-1.329*
Peru	EF	1.908	1.392	2.855	0.496	0.857**	-0.822
	GDP	2073.89	627.87	2725.82	229.079	0.170	0.332
Portugal	EF	4.096	3.093	5.4637	0.759	0.197	-1.568**
	GDP	7312.73	2474.41	11926.1	2960.23	0.045	-1.185*
Spain	EF	4.045	2.598	5.446	0.867	0.173	-1.203*
	GDP	9976.68	4116.75	16369.1	3416.14	0.218	-0.908
Sweden	EF	5.384	4.247	7.194	0.581	0.967***	1.046
	GDP	21148.6	11917.7	33259.3	5517.05	0.374	-0.580
Uruguay	EF	5.902	4.798	7.102	0.643	-0.024	-0.993
	GDP	5333.10	4009.72	7759.28	1083.38	0.527	-0.952

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively.

Table 2: Results of OLS estimations (data in level form).

Country	Function	b_0	$b_1{}^a$	$b_2{}^b$	$b_3{}^c$	R^2	LL	Results	Turning point
Argentina	Linear	-0.0618 (-1.226)	0.776 (0.624)			0.01	-13,813	No	
	Quadratic	-0.063 (-1.234)	-1.662 (-0.174)	0.175 (0.258)		0.01	-13.778	No	
	Cubic	-0.060 (-1.166)	33.162 (-0.601)	4.661 (0.600)	-0.209 (-0.580)	0.02	-13.594	No	
Brazil	Linear	-0.024^{*} (-1.695)	4.562^{***} (3.958)			0.26	48.658	Increasing	
	Quadratic	-0.023 (-1.553)	0.239 (0.047)	0.689 (0.864)		0.27	49.054	No	
	Cubic	-0.019 (-1.291)	-18.373 (-0.960)	7.292 (1.107)	0.747 (-1.010)	0.29	49.606	No	
Canada	Linear	-0.321^{*} (-1.710)	10.915^{***} (2.868)			0.16	-57.306	Increasing	
	Quadratic	-0.351^{*} (-1.870)	25.364^{**} (2.091)	-0.381 (-1.254)		0.19	-56.480	No	
	Cubic	-0.372^{*} (-1.874)	40.770 (0.900)	-1.286 (-0.500)	0.017 (0.353)	0.19	-56.412	No	
Chile	Linear	-0.051 (-1.407)	7.979^{***} (3.586)			0.23	9.400	Increasing	
	Quadratic	-0.037 (-1.038)	17.995^{***} (3.335)	-1.45^{**} (-2.024)		0.29	11.493	Inverted U-shaped	$6199.30
	Cubic	-0.035 (-0.975)	31.142^{*} (1.695)	-5.336 (-1.019)	0.338 (0.749)	0.30	11.799	No	
China	Linear	0.005 (0.395)	50.150^{**} (2.401)			0.12	59.330	Increasing	
	Quadratic	0.000 (0.001)	8.660 (1.176)	-1.203 (-0.516)		0.12	59.472	No	
	Cubic	-0.002 (-0.111)	12.606 (0.9375)	-4.974 (-0.454)	1.070 (0.352)	0.12	59.540	No	
Colombia	Linear	-0.037^{***} (-3.622)	6.443^{***} (4.050)			0.27	70.925	Increasing	
	Quadratic	-0.041^{***} (-3.817)	14.326^{**} (2.084)	-1.566 (-1.178)		0.29	71.656	No	
	Cubic	-0.040^{***} (-3.654)	-5.960 (-0.322)	5.593 (0.900)	0 (-1.179)	0.32	72.405	No	
France	Linear	-0.147^{**} (-2.635)	5.318^{***} (3.741)			0.24	9.897	Increasing	
	Quadratic	-0.146^{**} (-2.592)	5.845^{**} (2.040)	-0.023 (-0.282)		0.24	9.940	No	
	Cubic	-0.148^{**} (-2.574)	8.304 (0.821)	-0.191 (-0.286)	0.004 (0.254)	0.24	9.975	No	
India	Linear	-0.016^{**} (-2.664)	10.280^{***} (3.123)			0.18	96.719	Increasing	
	Quadratic	-0.018^{***} (-2.904)	20.269^{**} (2.1782)	-9.462 (-1.147)		0.21	97.413	No	
	Cubic	-0.018^{***} (-2.835)	20.416 (0.994)	-9.877 (-0.189)	0.323 (0.008)	0.21	97.413	No	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively. ^{a} values are multiplied by 10^4. ^{b} values are multiplied by 10^7. ^{c} values are multiplied by 10^{10}. The t-stat are given in parentheses.$EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + b_3 GDP_t^3 + \epsilon_t$. "No" means no relationship between GDP and EF.

Table 3: Results of OLS estimations (data in level form).

Country	Function	b_0	$b_1{}^a$	$b_2{}^b$	$b_3{}^c$	R^2	LL	Results	Turning point
Norway	Linear	-0.261 (-0.423)	4.685 (0.583)			0.01	-98.347	No	
	Quadratic	-0.305 (-0.467)	8.570 (0.454)	-0.060 (-0.229)		0.01	-98.319	No	
	Cubic	-0.382 (-0.534)	23.127 (0.416)	-0.604 (-0.307)	0.007 (0.279)	0.01	-98.277	No	
Paraguay	Linear	-0.045 (-1.554)	14.217^{**} (2.344)			0.11	13.615	Increasing	
	Quadratic	-0.047 (-1.492)	22.655 (0.516)	-3.267 (-0.194)		0.11	13.636	No	
	Cubic	-0.051 (-1.624)	334.18^{*} (1.6824)	-0.283 (-1.618)	80.872 (1.607)	0.16	15.008	No	
Peru	Linear	-0.031 (-1.548)	3.317^{*} (1.773)			0.07	28.059	Increasing	
	Quadratic	-0.030 (-1.484)	11.233 (0.642)	-1.871 (-0.455)		0.07	28.170	No	
	Cubic	-0.031 (-1.477)	25.627 (0.303)	-6.931 (-0.236)	0 (0.174)	0.07	28.186	No	
Portugal	Linear	-0.030 (-0.723)	2.788^{*} (2.011)			0.08	8.713	Increasing	
	Quadratic	-0.030 (-0.724)	4.096 (1.222)	-0.090 (-0.429)		0.09	8.812	No	
	Cubic	-0.028 (-0.648)	2.383 (0.237)	0.163 (0.115)	-0.011 (-0.1808)	0.09	8.830	No	
Spain	Linear	-0.033 (-0.621)	3.526^{**} (2.158)			0.10	10.421	Increasing	
	Quadratic	-0.035 (-0.658)	5.381 (1.613)	-0.086 (-0.640)		0.10	10.639	No	
	Cubic	-0.031 (-0.577)	1.209 (0.134)	0.362 (0.397)	-0.015 (-0.498)	0.11	10.774	No	
Sweden	Linear	-0.010 (-0.584)	2.547 (0.920)			0.02	-51.908	No	
	Quadratic	-0.140 (0.793)	10.443 (1.204)	-0.156 (-0.960)		0.04	-51.420	No	
	Cubic	-0.131 (-0.732)	0.914 (0.031)	0.280 (0.216)	-0.006 (-0.3387)	0.04	-51.357	No	
Uruguay	Linear	-0.063 (-1.050)	3.621 (1.578)			0.05	-21.254	No	
	Quadratic	-0.060 (-1.034)	31.340^{**} (2.3655)	-2.347^{**} (-2.122)		0.14	-18.964	Inverted U-shaped	\$6675.7
	Cubic	-0.060 (-1.019)	26.920 (0.306)	-1.577 (-0.103)	-0.043 (-0.051)	0.14	-18.963	No	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively. ^{a} values are multiplied by 10^4. ^{b} values are multiplied by 10^7. ^{c} values are multiplied by 10^{10}. The t-stat are given in parentheses.$EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + b_3 GDP_t^3 + \epsilon_t$. "No" means no relationship between GDP and EF.

Table 4: Results of OLS estimations (data in logarithm form).

Country	Function	b_0	b_1	b_2	b_3	R^2	LL	Results	Turning/ Inflection point
Argentina	Linear	-0.018 (-1.197)	0.247 (0.994)			0.02	42.360	No	
	Quadratic	-0.018 (-1.221)	-6.420 (-0.383)	0.379 (0.398)		0.03	42.445	No	
	Cubic	-0.017 (-1.118)	-759.539 (-0.933)	85.922 (0.929)	-3.238 (-0.925)	0.04	42.910	No	
Brazil	Linear	-0.008 (-1.471)	0.399^{***} (3.291)			0.20	95.012	Increasing	
	Quadratic	-0.007 (-1.394)	-5.920^{*} (-1.983)	0.400^{**} (2.118)		0.27	97.295	U-shaped	\$1635.98
	Cubic	-0.007 (-1.338)	-32.004 (-0.325)	3.729 (0.297)	-0.141 (-0.265)	0.28	97.333	No	
Canada	Linear	-0.059^{*} (-1.966)	3.339^{***} (3.310)			0.20	27.697	Increasing	
	Quadratic	-0.057^{*} (-1.891)	18.317 (0.778)	-0.778 (-0.637)		0.21	27.913	No	
	Cubic	-0.061^{*} (-1.997)	809.996 (0.902)	-83.046 (-0.890)	2.848 (0.882)	0.22	28.335	No	
Chile	Linear	-0.022 (-1.499)	1.166^{***} (4.349)			0.30	48.627	Increasing	
	Quadratic	-0.017 (-1.056)	6.485 (0.976)	-0.339 (-0.801)		0.31	48.968	No	
	Cubic	-0.017 (-1.045)	15.556 (0.085)	-1.468 (-0.065)	0.047 (0.050)	0.31	48.969	No	
China	Linear	-0.007 (-0.662)	0.321^{***} (2.764)			0.15	82.384	Increasing	
	Quadratic	-0.008 (-0.741)	0.152 (0.367)	0.016 (0.428)		0.15	82.482	No	
	Cubic	-0.005 (-0.500)	2.458 (0.814)	-0.392 (-0.740)	0.023 (0.771)	0.16	82.805	No	
Colombia	Linear	-0.020^{***} (-3.909)	0.747^{***} (4.248)			0.29	104.970	Increasing	
	Quadratic	-0.020^{***} (-3.713)	-1.384 (-0.369)	0.139 (0.568)		0.30	105.142	No	
	Cubic	-0.019^{***} (-3.683)	-94.857 (-0.771)	12.472 (0.768)	-0.542 (-0.760)	0.31	105.457	No	
France	Linear	-0.023^{**} (-2.120)	1.256^{***} (3.407)			0.21	79.409	Increasing	
	Quadratic	-0.029^{**} (-2.442)	-7.551 (-1.040)	0.476 (1.215)		0.24	80.185	No	
	Cubic	-0.032^{**} (-2.568)	179.409 (0.823)	-19.314 (-0.837)	0.698 (0.858)	0.25	80.585	No	
India	Linear	-0.017^{**} (-2.567)	0.415^{***} (3.010)			0.17	91.037	Increasing	
	Quadratic	-0.020^{***} (-2.864)	-1.437 (-1.188)	0.166 (1.541)		0.21	92.273	No	
	Cubic	-0.023^{***} (-3.466)	-48.638^{**} (-2.425)	8.410^{**} (2.403)	-0.476^{**} (-2.357)	0.31	95.130	Decreasing	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively.The t-stat are given in parentheses. $ln(EF_t) = b_0 + b_1 ln(GDP_t) + b_2 ln(GDP_t)^2 + b_3 ln(GDP_t)^3 + \epsilon_t$. "No" means no relationship between GDP and EF.

Table 5: Results of OLS estimations (data in logarithm form).

Country	Function	b_0	b_1	b_2	b_3	R^2	LL	Results	Turning point
Norway	Linear	−0.048 (−0.564)	2.097 (0.796)			0.01	-4.537	No	
	Quadratic	−0.049 (−0.556)	0.770 (0.022)	0.067 (0.038)		0.01	-4.536	No	
	Cubic	−0.059 (−0.639)	451.828 (0.409)	−45.258 (−0.408)	1.517 (0.409)	0.02	-4.445	No	
Paraguay	Linear	-0.013^{*} (−1.696)	0.454^{**} (2.303)			0.12	75.360	Increasing	
	Quadratic	−0.014 (−1.641)	1.488 (0.230)	−0.073 (−0.160)		0.11	75.374	No	
	Cubic	−0.013 (−1.590)	107.99 (0.493)	−15.396 (−0.489)	0.734 (0.487)	0.11	75.503	No	
Peru	Linear	−0.017 (−1.544)	0.385^{*} (1.970)			0.08	59.774	Increasing	
	Quadratic	−0.015 (−1.494)	4.313 (0.305)	−0.257 (−0.278)		0.08	59.816	No	
	Cubic	−0.015 (−1.457)	−85.093 (−0.107)	11.454 (0.109)	−0.511 (−0.112)	0.08	59.822	No	
Portugal	Linear	−0.006 (−0.631)	0.392^{*} (2.009)			0.08	74.180	Increasing	
	Quadratic	−0.007 (−0,677)	−0.937 (−0,285)	0.078 (0,405)		0.09	74.268	No	
	Cubic	−0.008 (−0.713)	16.299 (0.233)	−1.937 (−0.237)	0.078 (0.246)	0.09	74.301	No	
Spain	Linear	−0.007 (−0.545)	0.771^{**} (2.231)			0.10	69.772	Increasing	
	Quadratic	−0.010 (−0.693)	−1.802 (−0.340)	0.148 (0.487)		0.11	69.898	No	
	Cubic	−0.010 (−0.666)	−17.871 (−0.141)	1.948 (0.137)	−0.067 (−0.127)	0.11	69.907	No	
Sweden	Linear	−0.026 (−0.825)	1.316 (1.211)			0.03	27.286	No	
	Quadratic	−0.025 (−0.799)	6.338 (0.268)	−0.255 (−0.212)		0.04	27.311	No	
	Cubic	−0.025 (−0.773)	−725.622 (−0.808)	73.887 (0.813)	−2.501 (−0.815)	0.05	27.672	No	
Uruguay	Linear	−0.011 (−1.142)	0.409^{*} (1.898)			0.08	61.375	Increasing	
	Quadratic	−0.010 (−1.049)	17.427 (1.660)	−0.988 (−1.621)		0.13	62.739	No	
	Cubic	−0.010 (−1.014)	−698.883 (−1.233)	82.086 (1.248)	−3.210 (−1.264)	0.16	63.597	No	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively.The t-stat are given in parentheses. $ln(EF_t) = b_0 + b_1 ln(GDP_t) + b_2 ln(GDP_t)^2 + b_3 ln(GDP_t)^3 + \epsilon_t$. "No" means no relationship between GDP and EF.

Table 6: Results of long run OLS estimations (data in level form).

Country	Function	b_0	${b_1}^a$	${b_2}^b$	${b_3}^c$	b_4	R^2	LL	Results	Turning/ Inflection point
Brazil	Quadratic	-0.019 (-1.491)	-10.230^{*} (-1.963)	1.94^{**} (2.539)		-0.530^{***} (-3.880)	0.47	56.099	U-shaped	2636.598
	Cubic	-0.018 (-1.338)	-33.743 (-1.638)	10.468^{**} (1.373)	-0.979^{**} (-1.081)	-0.562^{***} (-3.857)	0.49	57.023	Inverted U-shaped	\$7128.362
Chile	Cubic	-0.079^{*} (-1.800)	1.239 (0.030)	4.214 (0.330)	-0.618 (-0.530)	-0.170^{*} (-1.772)	0.36	13.882	No	
China	Quadratic	-0.003 (-0.198)	26.934^{***} (2.738)	0.306 (0.135)		-0.128^{***} (-2.611)	0.24	62.931	Increasing	
India	Quadratic	0.021^{*} (1.748)	13.878 (1.226)	4.223 (0.222)		-0.298^{***} (-3.046)	0.41	104.293	No	
Spain	Cubic	0.050 (0.892)	59.793^{**} (2.335)	-5.737^{**} (-2.354)	0.188^{**} (2.510)	-0.400^{***} (-3.253)	0.30	16.385	Increasing/N-shaped	\$10171.99
Sweden	Linear	0.156 (1.090)	1.143 (0.521)			-0.807^{***} (-5.312)	0.41	-40.303	No	
Uruguay	Linear	-0.029 (-0.532)	3.801^{*} (1.853)			-0.328^{***} (-3.480)	0.26	-21.254	Increasing	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively.^{a} values are multiplied by 10^4. ^{b} values are multiplied by 10^7. ^{c} values are multiplied by 10^{10}. The t-stat are given in parentheses. $EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + b_3 GDP_t^3 + b_4 EC_{t-1} + \epsilon_t$, where EC_{t-1} is an error-correction term between EF and GDP. "No" means no relationship between GDP and EF.

Table 7: Results of long run OLS estimations (data in logarithm form).

Country	Function	b_0	b_1	b_2	b_3	b_4	R^2	LL	Results	Turning/ Inflection point
Brazil	Quadratic	-0.007 (-1.605)	-8.730^{***} (-3.174)	0.559^{***} (3.236)		-0.483^{***} (-3.616)	0.45	103.528	U-shaped	\$2462.67
	Cubic	-0.008 (-1.660)	71.674 (0.561)	-9.763 (-0.598)	0.441 (0.634)	-0.499^{***} (-3.513)	0.45	103.759	No	
Chile	Cubic	-0.023 (-1.213)	-91.984 (-0.300)	12.254 (0.320)	-0.536 (-0.337)	0.002 (0.061)	0.32	49.264	No	
China	Quadratic	0.064^{***} (3.043)	-1.038^{**} (-2.171)	0.138^{***} (3.045)		-0.478^{***} (-3.795)	0.37	89.262	Increasing	
	Cubic	0.196^{***} (15.760)	1.481 (0.413)	-0.508 (-0.826)	0.053 (1.555)	0.957^{***} (7.392)	0.95	77.754	No	
Uruguay	Linear	-0.005 (-0.534)	0.416^{**} (2.158)			-0.312^{***} (-3.441)	0.27	66.969	Increasing	
	Quadratic	-0.005 (-0.572)	13.771 (1.452)	-0.776 (-1.411)		-0.328^{***} (-3.379)	0.31	68.270	No	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively. The t-stat are given in parentheses. $ln(EF_t) = b_0 + b_1 ln(GDP_t) + b_2 ln(GDP_t)^2 + b_3 ln(GDP_t)^3 + b_4 EC_{t-1} + \epsilon_t$, where EC_{t-1} is an error-correction term between EF and GDP. "No" means no relationship between GDP and EF.